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An X-ray Micro-focusing System using Differentially Deposited Elliptical Mirrors at NSLS X13B

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Beamline(s): X13B

Introduction: Of the variety of ways of focusing x-rays to sub-micron dimensions, elliptical mirrors in the Kirkpatrick-Baez (KB) arrangement are extremely attractive [1]. They can be used for both white beam and monochromatic beam applications, the focal length is fixed and independent of x-ray energy, and they are extremely efficient in higher order harmonic rejection. At X13B, we have designed a rhodium-coated KB system to focus x-rays to a spot size of 3 μm (vertical) x 9 μm (horizontal) at a long working distance of 23 cm, using a novel differential deposition technique [1],[2]. As this manufacturing process can achieve figure (slope) errors of less than 1 μ radians, focusing to sub-micron spatial dimensions is possible.

Methods and Materials: The KB system was arranged as shown in Fig. 1. Both mirrors were 10 cm in length and the upstream and downstream optics provided vertical and horizontal focusing respectively. Both optics were mounted onto high-resolution translation/rotation stages to provide the necessary degrees of freedom, to align them with the incident x-ray beam. Both mirrors were set at a grazing-incidence angle of 3.8 mrad, and the complete system was set up on a heavy granite table to provide good vibrational damping.

Results: Fig 2. Shows the focused x-ray beam dimension in the vertical direction, measured by scanning a tantalum knife edge across the focal spot, and detecting the transmitted beam using a silicon pin diode. Using these optics, a calcium fluorescence map of osteoarthritic monkey tibia was performed and the results are shown in Fig. 3. The high-resolution of the KB instrument is clearly evident.

Conclusions: The design of a KB system using a novel differential deposition technique has been successfully implemented at the NSLS X13B end-station. These optics perform to expectations, and sub-micron focusing will be implemented in the near future at X13B.

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References:

[1]. J.M. Ablett, C.C. Kao and A. Lunt, “The design and performance of an x-ray micro-focusing system using differentially deposited elliptical mirrors at the National Synchrotron Light Source”, Rev. Sci. Instrum. 73(10) 2002.
[2]. G.E. Ice, J.-S. Chung, J.Z. Tischler, A. Lunt and L. Assoufid, “Elliptical x-ray microprobe by differential deposition”, Rev. Sci. Instrum. 71(7) 2000.

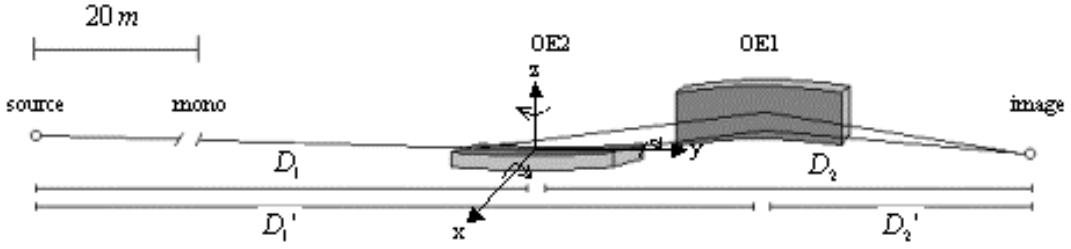

Fig. 1 X13B X-ray micro-focusing configuration. X-rays from either the X13 undulator or wiggler sources are focused in both the vertical and horizontal directions by the pair of elliptical mirrors (OE2 and OE1). The source-to-mirror distances are 25.5 (D1) and 25.62 m (D1’), and the mirror-to-image distances are 0.4 (D2) and 0.28 m (D2’).

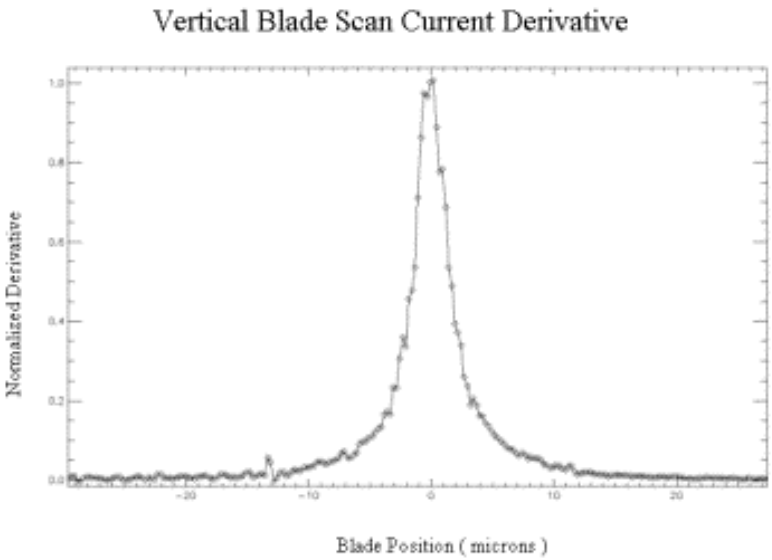

Fig. 2. The derivative of the knife-edge scan in the vertical dimension.The full-width-at-half-maximum is only 3 microns, at a focal length of 0.4 meters.

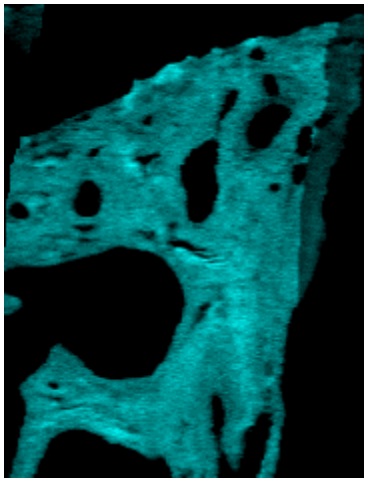

Fig.2. Calcium fluorescence map of osteoarthritic monkey tibia. The lighter colors indicated elevated levels of calcium concentration.